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Optical image fibre base material mfg. method - assembling strands of more than two different diameters and arranging them at random and covering with integrated cladding

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The image fibre comprises cores (10,11,12) and and integrated cladding (3) covering them. The dias. of the cores are all different and increase in order from the first to the (10) third (12). The mfg. method comprises assembling the optical fibre strands of more than two different dias. The image fibre material is formed of a number of strands in longitudinally drawn and aligned state.

The method eliminates previous disadvantages by arranging the cores at random and reduces a Moire produced in case of connection to a TV camera. It also does not produce dislocations or pinholes of core arrangement in the section of the image fibre since a number of cores are at random and are covered with an integrated cladding. The thicknesses of the claddings of each individual fibre are the same. The image fibre is connected to a T.V. camera. (18pp Dwg.No.0/6)

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(54) Image fiber and method of fabricating base material for the same.

(57) An image fiber which includes a number of cores arranged at random and covered with an integrated clad. A method of fabricating an image fiber base material collected with a number of optical fiber strands in longitudinally drawn and aligned state comprising the steps of assembling the optical fiber strands of more than two different diameters from each other. In this manner, this method can eliminate the drawbacks of the conventional image fiber by arranging cores at random and can reduce a moire produced in case of connecting to a TV camera, and does not produce dislocations or pinholes of core arrangement in the section of the image fiber since a number of cores of the image fiber are arranged at random and are covered with integrated clad.

FIG.5

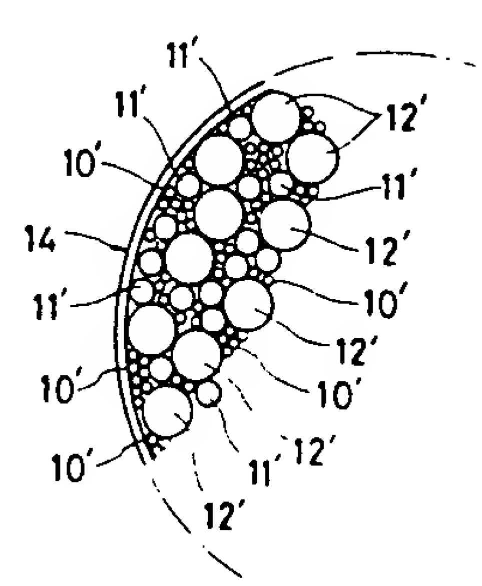

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IMAGE FIBER AND METHOD OF FABRICATING BASE MATERIAL FOR THE SAME

This invention relates to an image fiber used to transmit an image and a method of fabricating a base material for the image fiber.

An image fiber, which is also called "an image guide", is ideally constructed to densely arranged a number of cores by suppressing the irregularity in the diameter of a core as small as possible. The image fiber further prevents a light from leaking by increasing its NA, the diameter of the core and the thickness of a clad.

Two conventional representative examples of a method of fabricating an image fiber will be described. One of them includes the steps of arranging, as shown in Fig. 1, several thousands to several ten thousands of optical fiber strands 1, 1, 1,.. of the same diameter so as to externally contact with each other in case of filling the strands in a pipe of the same material as the strands, filling the strands thus arranged in the pipe, and then simultaneously drawing the strands 1, 1, 1,.. together with the pipe under heated state, thereby melting and integrating the strands. The other method includes the steps of filling optical fiber strands 1, 1, 1,.. in a pipe, arranging the strands via a water stream or via a supersonic vibration, and then simultaneously drawing the

strands 1, 1, 1,.. in the same manner as the first method.

Fig. 2 shows the strand filling state of the image fiber produced according to the above-mentioned both methods. As obvious in Fig. 2, when the strands 1, 1, 1,.. are filled in the pipe 2 of quartz, air gap S is formed between the strands 1, 1, 1,.. and the pipe 2.

When the image fiber of this state is collapsed or is directly drawn, the pipe 2 is reduced in its diameter, the pipe reducing force is applied only to the partial strands 1a, 1a contacted with the pipe 2 at the initial time of reducing the pipe 2. Accordingly, the arrangement of the strands 1, 1, 1,.. is disordered.

In this case, since the filling density of the strands 1, 1, 1,.. is high and the arranging state is considerably stabilized, an extreme disorder of the arrangement does not occur, but as shown in Fig. 3, the arrangement is partially displaced, and cracked disorders (a dislocation of arrangement) 4, 4, 4,.. occur among the arranging regions 3, 3, 3,..

In case of the image fiber thus obtained, the dislocations of the arrangement of the strands not only become an obstacle to the observation of the arrangement, but also cause a partial decrease in the quality of an image and, since the image fiber is formed in an arranging pattern, a moire occurs in case that the image fiber is connected to a TV camera.

The moire occurs, as known per se, when the array of

picture elements substantially coincides with the space frequency of a TV scanning line.

Accordingly, a primary object of this invention is to provide an image fiber which can eliminate the drawbacks of the conventional image fiber by arranging cores at random and can reduce a moire produced in case of connecting to a TV camera.

Another object of the present invention is to provide an image fiber which does not occur a visual disorder with dislocations of the arrangement of cores from the result that, even if small disorder occurs between the adjacent optical fiber strands arranged at random, the strands are rearranged in a new random arrangement.

Still another object of the present invention is to provide a method of fabricating an image fiber which does not produce dislocations or pinholes of core arrangement in the section of the image fiber since a number of cores of the image fiber are arranged at random and are covered with integrated clad.

Still another object of the invention is to provide a method of fabricating an image fiber in which a picture of good contrast can be obtained due to the reduction in the leakage of a light, a uniform quality of picture can be obtained by the random arrangement of the cores, and a moire can hardly occur even at the connection to a TV camera.

The above and other related objects and features of the invention will be apparent from a reading of the following description of the disclosure found in the accompanying drawing and the novelty thereof pointed out in the appended claims.

Fig. 1 is an explanatory view showing the array of conventional optical fiber strands;

Fig. 2 is a sectional view of a base material for the conventional image fiber;

Fig. 3 is a sectional view of an image fiber obtained from the base material;

Fig. 4 is a sectional view of an embodiment of an image fiber according to the present invention;

Fig. 5 is a sectional view showing the base material of the image fiber;

Fig. 6 is a sectional view showing the array of the optical fiber strands to improve the light leakage characteristic.

The present invention will now be described in more detail with reference to the accompanying drawings.

In Fig. 4, which shows an embodiment of an image fiber according to the present invention, an image fiber comprises cores 10, 10, 10,.., 11, 11, 11,.., 12, 12, 12,.., and a clad 13 for covering the cores 10, 10, 10,.., 11, 11, 11,.., and 12, 12, 12,.. The cores 10, 11, 12 are arranged at random

in the section, and are not isolated at each core, but are integrated. Further, the diameters of the cores 10, 11, 12 are formed differently in the relationship of 10<11<12.

Fig. 5 shows another embodiment of an image fiber according to the present invention. The image fiber as shown in Fig. 4 is obtained by a method of fabricating the image fiber which comprises the steps of filling optical fiber strands 10', 10', 10',.., 11', 11', 11',.., and 12', 12', 12',.. of more than two different diameters in a glass pipe 14, then collapsing by heating the pipe 14 filled with the optical fiber strands, or drawing the pipe without through the collapsing step in heating state.

In this case, the ratio of the optical fiber strands 10', 10', 10',.. (similarly 11', 11', 11',.. and 12', 12', 12',..) belonging to one type of diameter to the entire number of pieces may be more than 30%, and the difference in diameter of the strands (10' and 11', 11' and 12') having the nearest diameters may be set to more than 5%.

In the image fiber thus obtained by mixing and disposing the optical fiber strands of more than two different diameters, the cores are arranged at random in the section, and a moire produced in case of connecting to a TV camera can be accordingly reduced.

In addition, in the image fiber thus obtained has no dislocation of arrangement of the cores, because when the

optical fiber strands of more than two different diameters are mixed, the strands are arranged at random.

In other words, even if a small disorder in the arrangement of the cores occurs among adjacent strands in the state that the strands are arranged at random, the strands are rearranged in new random arrangement, with the result that, since the strands are rearranged from the old random arrangement to the new random arrangement, a visual disorder which causes a dislocation does not occur.

The characteristics of the image fiber according to the present invention when the diameters of the cores are different will be described in comparison with that of the conventional image fiber.

The state of transmitting a light in the core generally depends upon the normalized frequency v designated by the following equations in a step index type.

$$v^2 = w(\varepsilon_1 - \varepsilon_2)\mu_0 a^2 \ldots \quad (1)$$

where

w: Angular frequency of a light to be transmitted

ε_1, ε_2: Dielectric constants of the core and the clad

μ_0: Vacuum magnetic permeability

a: Diameter of core

In the above equation (1), the state of the mode excited by the core is represented by the v, and the mode is propagated as the wave of phase constant β having a function of the v.

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In this case, by considering the coupling of electric power between two cores, the following coupling equation can be obtained.

$$\frac{dA}{dZ} = -\beta aA + KabB... \quad (2)$$

$$\frac{dB}{dZ} = -\beta bA + KabB... \quad (3)$$

where

Kab: Coupling coefficient (which depends upon the state of the mode and the interval of cores.)

A, B: Amplitudes of transmitting mode in the cores a, b.

βa, βb: Phase constants of the transmitting mode in the cores a, b.

Z: coordinates variables in propagating direction

When the equations (2) and (3) are solved, the following answers can be obtained.

i) In case of Kab $\gg$ (βa - βb)/2

Electric power is substantially completely converted between the cores a and b, the core a is transferred substantially, and the core a is substantially completely converted the core b while the light is propagated at a predetermined distance.

ii) In case of Kab $\ll$ (βa - βb)/2

No electric power is substantially converted between the cores a and b, and the core a is propagated as it is through the core a.

Since the interval between the cores is short in case of the image fiber, the Kab is considerably large, and the Kab becomes extremely large in the mode in the vicinity of the cut-off frequency.

The wavelength to be used is in the range of visible light in the mode of the cut-off frequency, and the range of the wavelength to be transmitted is wide, and this mode should exist in any wavelength in this range.

In the conventional image fiber, the diameter and refractive index difference of the cores are all the same in all the cores, $\beta a = \beta b$ accordingly exists in one mode, this corresponds to the case of the above paragraph i) as described above, and the leakage of the light becomes remarkable.

On the other hand, the image fiber of different diameter of the cores according to the present invention has more than two different diameters as described above in the range, and the values of v differ between the images of the conventional one and the present invention, becoming $\beta a \neq \beta b$.

In other words, in the image fiber of the present invention, the conditions described in the above paragraph ii) can be satisfied, thereby extremely reducing the oozing of the light.

In order to raise this effect, it is preferred to form the diameters of the adjacent cores different from each other

in the image fiber, and in order to perform the different diameters of the adjacent cores, at least three types of optical fiber strands 10', 10', 10',.., 11', 11', 11',.., and 12', 12', 12' are employed so that the cores of the same diameter are not disposed adjacent to each other in the array as shown in Fig. 6 and are drawn by the means as described above.

In view of the leakage of the light, the difference of the diameters of the cores of different diameters in the image fiber is discovered to be more than 5%. If the difference of the diameters of the cores is larger than required, the resolution of the image at the core having larger diameter decreases, and in case of considering the remedy against this drawback and the arrangement of the strands at the fabricating time, the difference of the cores of the different diameters is discovered to be set to the range as below:

$$0.7 \leqq d\ min. / d\ max. \leqq 0.9$$

where

d min: the diameter of the minimum core

d max: the diameter of the maximum core

Examples of the present invention will be described:

EXAMPLE 1

5,000 pieces of optical fiber strands, each having 275 µm of diameter of each strand and 200 µm of diameter of each core,

and 5,000 pieces of optical fiber strands, each having 325 μm of diameter of each strand and 200 μm of diameter of each core were mixed, the mixture was then densely filled in a quartz tube, and an image fiber was then fabricated according to an ordinary method.

Since this image fiber is fabricated by mixing the optical fibers of more than two different diameters and arranging the mixture, it does not have a dislocation, and when the respective optical fiber strands were densely filled in the quarts tube, the strands could be densely filled, and were arranged stably at random, thereby eliminating a pinhole and enabling to transmit a preferable image.

EXAMPLE 2

1,000 pieces of optical fiber strands, each having 2/3 of ratio of core diameter/strand diameter and 400 μm of diameter of each strand, and 2,000 pieces of optical fiber strands, each having 300 μm of diameter of each strand were densely filled in a quartz tube, and an image fiber was fabricated by an ordinary method.

In case of this image fiber, the array of picture elements (cores) was at random, no dislocation nor defect of chrysanthemum pattern was observed, and the improvement from the conventional image fiber could be confirmed.

However, since the number of picture elements (cores) were less like 3,000 pieces, the decrease in the quality of

a picture was observed.

EXAMPLE 3

5,000 pieces of optical fiber strands, each having 275 μm of diameter of each strand and 183 μm of diameter of each core, and 5,000 pieces of optical fiber strands, each having 325 μm of diameter of each strand and 216 μm of diameter of each core were mixed, the mixture was densely filled in a quartz tube, and an image fiber was fabricated by an ordinary method.

EXAMPLE 4

3,400 pieces of optical fiber strands, each having 275 μm of diameter of each strand and 183 μm of diameter of each core, 3,400 pieces of optical fiber strands, each having 300 μm of diameter of each strand and 200 μm of diameter of each core, and 3,400 pieces, each having 325 μm of diameter of each strand and 216 μm of diameter of each core were mixed, the mixture was densely filled in a quartz tube, and an image fiber was fabricated by an ordinary method.

No dislocation nor defect of chrysanthemum pattern was observed in the same manner as the Example 2 in the image fibers of the above Examples 3 and 4.

EXAMPLE 5

3,400 pieces of optical fiber strands, each having 270 μm of diameter of each strand and 180 μm of diameter of each core, 3,400 pieces of optical fiber strands, each having

300 μm of diameter of each strand and 200 μm of diameter of core, and 3,400 pieces of optical fiber strands, each having 330 μm of diameter of each strand and 220 μm of diameter of each core were mixed, the mixture was filled in a quartz tube to produce a predetermined base material, and the material was treated to fabricate an image fiber by an ordinary method.

No pinhole which caused by the mixing degree of picture elements (cores) and by the defect of chrysanthemum pattern was observed and crosstalk characteristic were excellent as compared with that fabricated in the Example 4, in the image fiber fabricated in the Example 5.

The conditions that more than two types of the core diameters are included when the image fiber having the cores of different diameters is fabricated are satisfied, the optical fiber strands in which the ratio of the core diameter to the optical fiber strand diameter is constant may be used, the optical fiber strands having constant thicknesses of all the clads may be used, and the optical fiber strands in which the core diameter, the ratios of the core diameter to the optical fiber strands diameter and the thickness of the clads are different from each other may be employed.

According to the image fiber fabricated by the method of the present invention as described above, a number of cores are advantageously arranged at random, and the cores are

covered with integrated clad. Accordingly, no dislocation of core arrangement nor pinhole can be observed in the section of the image fiber by the random arrangement of the cores.

Further, the image fiber fabricated by the method of present invention has more than two different diameters of the cores. Accordingly, the leakage of the light can be reduced, thereby obtaining an image of preferable contrast, uniform quality of picture by the random arrangement of the cores, and a moire hardly occurs even in the connection to a TV camera.

According to the method of the present invention, the optical fiber strands having more than two different diameters of strands are advantageously assembled when the base material for the image fiber is produced by assembling a number of optical fiber strands in the longitudinally drawing and aligning state. Therefore, in case of fabrication, the optical fiber strands can be densely filled in a quartz tube, and the image fiber having no dislocation nor pinhole can be simply fabricated.

CLAIMS:

1. An image fiber comprising:

a number of cores arranged at random and covered with an integrated clad.

2. The image fiber as claimed in claim 1, wherein said cores are formed in more than two different diameters.

3. A method of fabricating an image fiber base material collected with a number of optical fiber strands in longitudinally drawn and aligned state comprising the steps of:

assembling the optical fiber strands of more than two different diameters from each other.

4. The method as claimed in claim 3, wherein the ratio of the diameter of said core to the diameter of said optical fiber strand is constant in all the optical fiber strands.

5. The method as claimed in claim 3, wherein the ratio of the pieces of the optical fiber strands of each type occupying in the entirety is more than 30%.

6. The method as claimed in claim 3, wherein the difference of the outer diameter of the optical fiber strands having the diameter nearest to each other is more than 10%.

7. The method as claimed in claim 3, wherein the thicknesses of the clads in the respective optical fiber strands are equal to each other.

8. The method as claimed in claim 3, wherein the diameter

of said core in said optical fiber strands, the ratio of the diameter of said optical fiber strand to the diameter of said core, and the thickness of said clad are different from each other in the respective optical fiber strands.

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FIG. 1

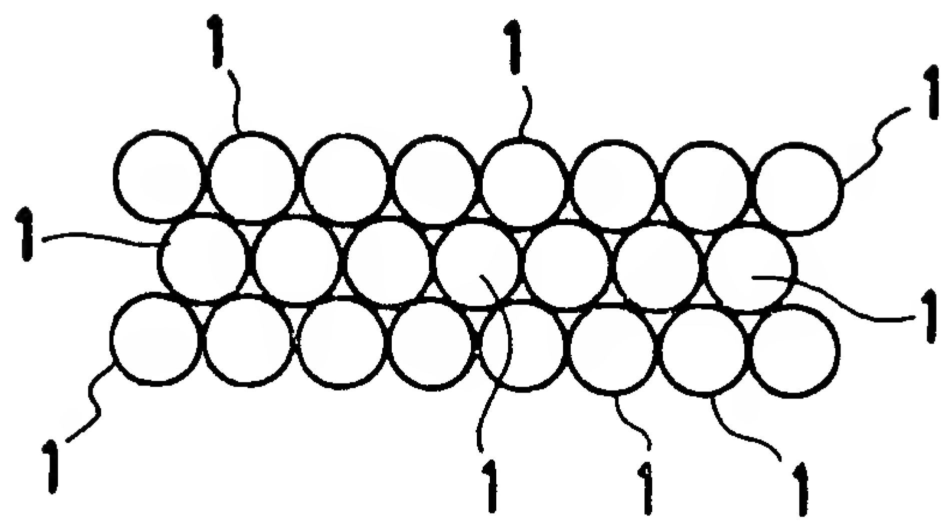

FIG. 2

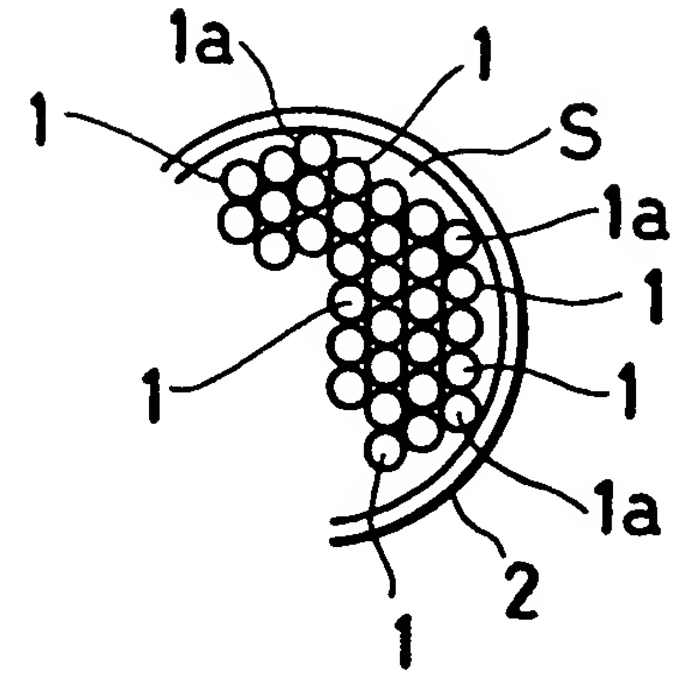

FIG. 3

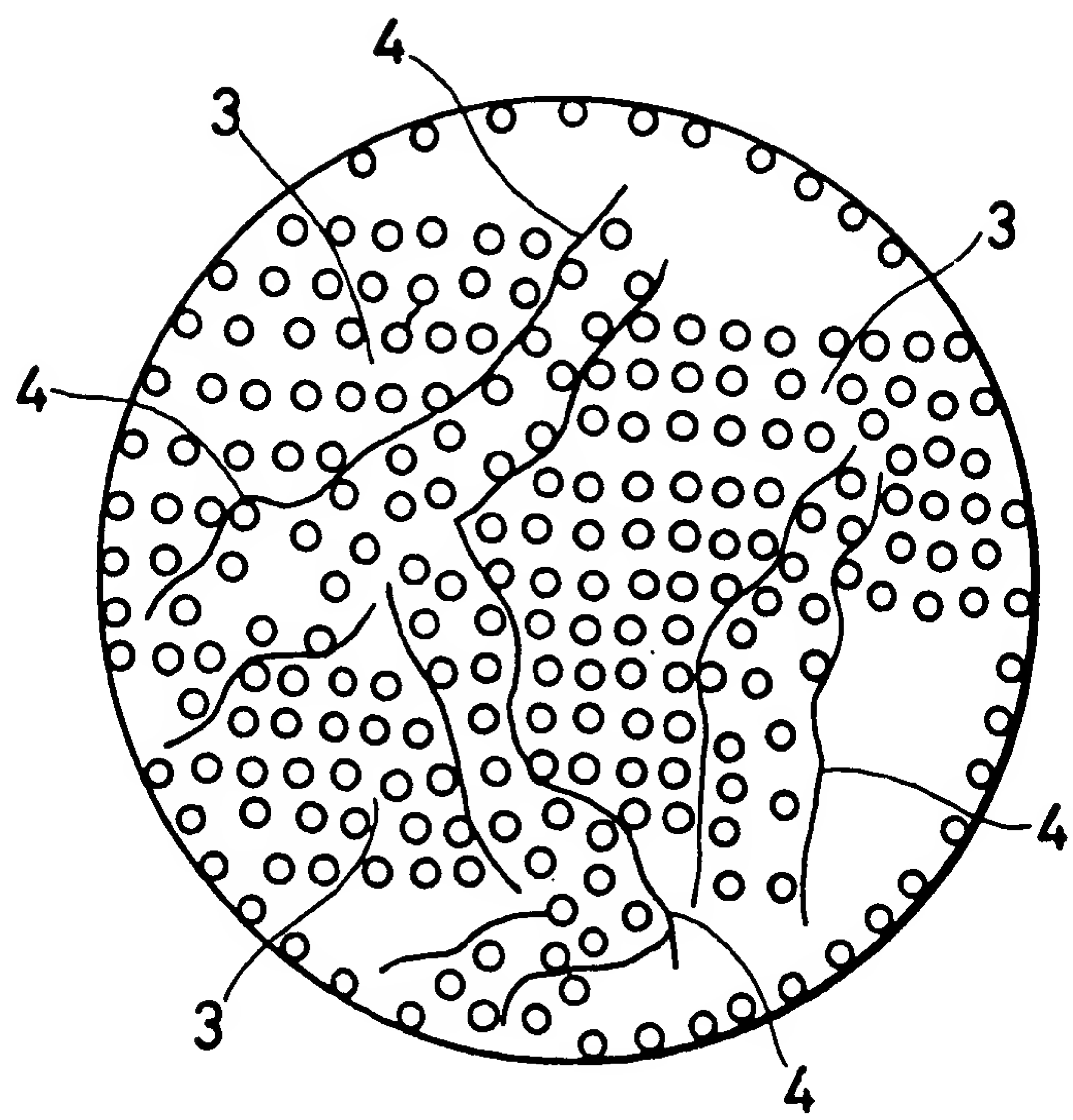

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FIG. 4

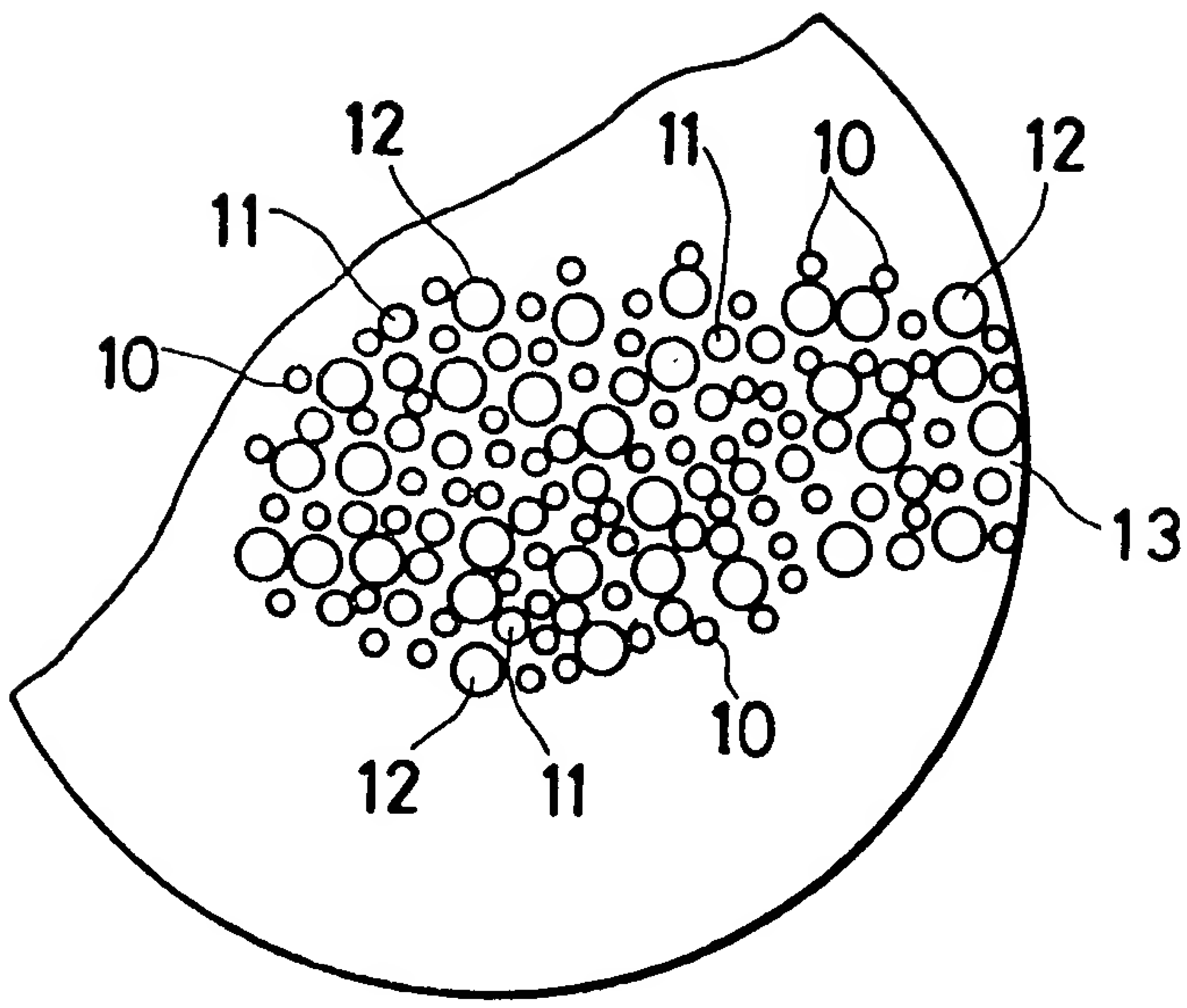

FIG. 5

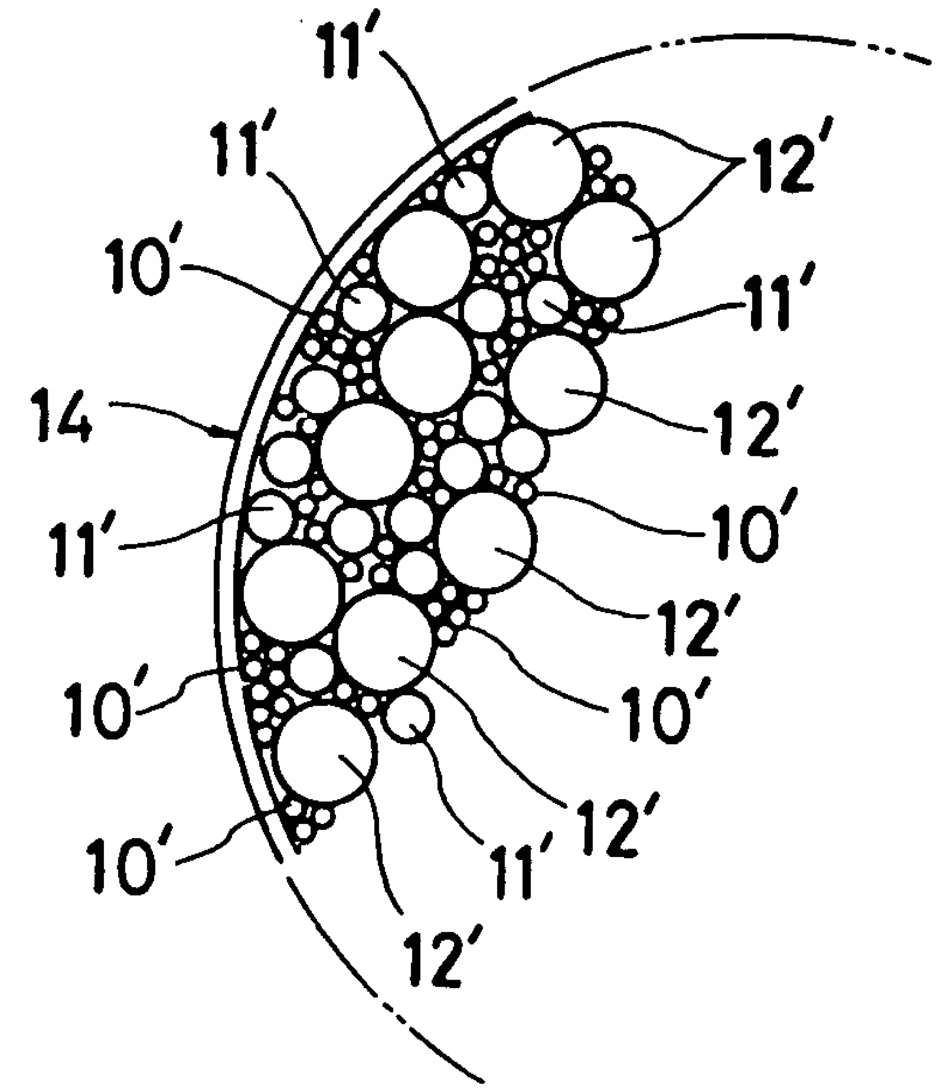

FIG. 6